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**APPLICATION  
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**APPLICANT'S: SATOSHI DOI**

**FOR: INTERCONNECTIONS INCLUDING MULTI-  
LAYER METAL FILM STACK FOR  
IMPROVING CORROSION AND HEAT  
RESISTANCES**

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**INTERCONNECTIONS INCLUDING  
MULTI-LAYER METAL FILM STACK  
FOR IMPROVING CORROSION AND HEAT RESISTANCES**

5                    **Background of the Invention**

1. Field of the Invention

The present invention is generally related to a method of fabricating interconnections including a multi-layer metal film stack, particularly, to an improvement in corrosion and heat resistances of interconnections.

2. Description of the Related Art

TFT (thin film transistor) apparatuses, such as LCDs (liquid crystal displays), require low resistivity interconnections with high corrosion and heat resistances. A technique for fabricating such interconnections is disclosed in Japanese Patent Application No. Jp-A-Heisei 8-62628. The disclosed technique involves forming a refractory metal film, oxidizing the surface of the refractory metal film, forming an aluminum film on the oxidized surface, oxidizing the upper surface of the aluminum film, forming another refractory metal film on the oxidized surface of the aluminum film to complete a film stack, patterning the film stack, and oxidizing sides of

the film stack. The oxides effectively avoids the aluminum film being corroded by stripping agent for stripping off resist patterns used as a mask.

Japanese Patent Application No. P2000-

5 26335A discloses an interconnections structure composed of an aluminum film sandwiched by a pair of refractory metal films. Oxygen including aluminum films are disposed between the aluminum film and refractory metal films to prevent  
10 thermally induced counter diffusion between the aluminum film and refractory metal films.

Japanese Patent Application No. P2002-

198360 discloses an etching technique for etching a structure including a silicon layer, and an  
15 aluminum layer disposed on the upper surface of the silicon layer. The disclosed etching technique involves etching the aluminum layer with  $\text{Cl}_2$  gas and  $\text{H}_2$  gas, and etching the silicon layer with  $\text{SF}_6$  gas, and  $\text{HCl}$  gas and  $\text{He}$  gas. The  
20 document also discloses the use of  $\text{Cl}_2$  gas in place of the  $\text{HCl}$  gas.

Japanese Patent Application No. P2002-

90774A discloses a LCD fabrication process to reduce deterioration of liquid crystal within  
25 cells caused by pollution with material of gate electrodes. The disclosed process involves successively depositing an aluminum layer and a

molybdenum layer, partially etching the molybdenum layer in an effective display region of the display panel, and oxidizing the aluminum layer in the effective display region through an  
5 anodization technique to complete the gate electrodes.

Japanese Patent Application No. 2000-252473 discloses a TFT structure for achieving low resistivity ohmic contact onto gate electrodes.  
10 The disclosed TFT structure is composed of gate electrodes including first through third metal layers, the first metal layer being formed of refractory metal such as Ta, Hf, Nb, and Zr, the second metal layer being formed of low  
15 resistivity metal such as Al, Ti, Cu, Cr, W, and Mo, and the third metal layer being formed of refractory metal such as Ta, Hf, Nb, and Zr.

#### Summary of the Invention

20 In summary, the present invention addresses an improvement in corrosion and heat resistances of interconnections, especially those integrated within TFT devices.

In an aspect of the present invention, a  
25 method of fabricating a semiconductor device including an interconnection is composed of:  
forming a metal film stack to cover a

substrate; the film stack including:

a lower refractory metal film over the substrate,

a lower protective layer of a first  
5 compound including metal disposed on an upper surface of the lower refractory metal film,

a core metal film of the metal on an upper surface of the lower protective layer,

an upper protective layer of a second  
10 compound including the metal disposed on an upper surface of the core metal film, and

an upper refractory metal film disposed on an upper surface of the upper protective layer;

15 patterning the metal film stack; and  
forming a side protective layer of a third compound including the metal on a side of the patterned core metal film.

At least one of the first, second, and  
20 third compounds may be oxide, nitride, or oxynitride of the metal.

In the event that the metal is selected from among the group consisting of aluminum and aluminum alloy, the first, second, and third  
25 compounds are preferably selected from the group consisting of oxide, nitride, and oxynitride of the metal.

For copper, silver, and an alloy thereof,  
by contrast, the first, second, and third  
compounds are preferably selected from the group  
consisting of nitride, and oxynitride of the  
5 metal.

The patterning may include:

forming a resist pattern on the metal film  
stack, and

etching the metal film stack using the  
10 resist pattern as a mask, the formation of the  
side protective layer being implemented before  
the resist pattern is stripped off.

Alternatively, the patterning may include:

forming a resist pattern on the metal film  
15 stack,

etching the metal film stack using the  
resist pattern as a mask, and

stripping off at least a portion of the  
resist pattern, the formation of the side  
20 protective layer being implemented after the  
stripping off.

The method may further includes:

forming a semiconductor film stack to cover  
the substrate; the semiconductor film stack  
25 including a semiconductor layer and a heavily  
doped semiconductor layer disposed on an upper  
surface of the semiconductor layer, and the metal

film stack being patterned so that the patterned metal film stack overlaps the semiconductor film stack;

          patterning the semiconductor film stack  
5 using the patterned film stack as a mask.

          When the method includes covering the substrate with a semiconductor film stack including a semiconductor layer and a heavily doped semiconductor layer disposed on an upper  
10 surface of the semiconductor layer, and patterning the semiconductor film stack, the patterning the metal film stack may include:

          forming a resist pattern on the metal film stack,

15           etching the metal film stack using the resist pattern as a mask so that the patterned metal film stack overlaps the semiconductor film stack, and

          the patterning the semiconductor film stack  
20 may be achieved by using the resist pattern as a mask.

          The above-mentioned method is especially effective in the case that the patterning the semiconductor film stack is achieved by using an  
25 etchant including fluorine and/or chlorine.

#### **Brief Description of the Drawings**

Figs. 1A through 1F are cross sectional views illustrating a fabrication process of an inversely staggered TFT device in an embodiment of the present invention; and

5 Figs. 2A through 2G are cross sectional views illustrating a fabrication process in an alternative embodiment.

#### **Description of the Preferred Embodiments**

10 Preferred embodiments of the present invention are described below in detail with reference to the attached drawings.

In one embodiment, as shown in Fig. 1A, a process for fabricating a TFT device begins with forming a gate electrode 2 and a scan line (not shown) on a transparent insulating substrate 1. In order to form the gate electrode 2, a core metal film 21 of aluminum is firstly deposited on the substrate 1, and then the surface of the metal film 21 is covered with a thin protective film 22. The protective film 22 may be formed through oxidizing, nitriding, or oxinitriding the surface of the core metal film 21. A refractory metal film 23 of chromium is then deposited on the protective film 22. The core metal film 21, the protective film 22, and the refractory metal film 23 is then patterned. After the patterning,



the sides of the patterned core metal film 21 are oxidized, nitrided, or oxinitrided to form thin protective films thereon, which typically have a thickness in the orders of tens or hundreds of  
5 nano meters. This completes the gate electrode 2.

After the gate electrodes 2 are covered with a gate dielectric 5, as shown in Fig. 1B, a semiconductor film stack 6 of an amorphous  
10 silicon film 61 and a heavily doped amorphous silicon film 62 is then formed to cover the gate dielectric 5.

As shown in Fig. 1C, the semiconductor film stack 6 is then patterned to form a semiconductor  
15 film stack 6.

After patterning the semiconductor film stack 6, as shown in Fig. 1D, a metal film stack of a lower refractory metal film 91, a lower protective film 93a, a core metal film 92, an  
20 upper protective film 93b, and an upper refractory metal film 94 is then formed to cover the patterned semiconductor film stack 6.

The refractory metal films 91 and 94 are formed of a material selected from the group of  
25 chromium (Cr), titanium (Ti), tantalum (Ta), Niobium (Nb), hafnium (Hf), zirconium (Zr), molybdenum (Mo), tungsten (W), alloys thereof,

and conductive nitrides thereof, such as titanium nitride.

The core metal film 92 is formed of a low resistivity metal, such as aluminum, copper,  
5 silver, and alloys mainly consisting of these metal, such as AlNd.

The protective films 93a and 93b are formed of oxides, nitrides, or oxynitrides of the metal or alloy used as the core metal films 92. In the  
10 event that the core metal film 92 is formed of aluminum, or aluminum alloy, any of the oxides, nitrides, or oxynitrides thereof is suitable for the protective films 93a and 93b. For copper, silver, and alloys thereof, by contrast, the use  
15 of the oxides as the protective films 93a and 93b is not preferable because of the poor corrosion resistivity thereof.

The lower protective film 93a may be formed through any of three processes described below.

20 A first process for forming the lower protective film 93a involves oxidizing the upper surface of the lower refractory metal film 91 through plasma modification or O<sub>2</sub> annealing after cleaning the upper surface, and depositing the  
25 core metal film 92 on the oxidized surface. The oxidized surface of the lower refractory metal film 91 provides oxygen for the bottom portion of

the core metal film 92, and thereby completes the lower protective film 93a of an oxide of the core metal film 92.

A second process for forming the lower protective film 93a involves reactive sputtering with a sputtering gas including  $O_2$ ,  $N_2$ , or  $N_2O$  gas as well as Ar gas at the initial deposition stage of the core metal film 92. This achieves deposition of the lower protective film 93a of an oxide, nitride, or oxynitride of the core metal film 92. After the completion of the lower protective film 93a, the sputtering gas is then switched to pure Ar gas to deposit the core metal film 92.

A third process for forming the lower protective film 93a involves depositing the metal used as the core metal film 92, and oxidizing or nitrizing the deposited metal through  $O_2$  plasma treatment,  $N_2$  plasma treatment, or annealing in an oxidizing atmosphere. The oxidizing or nitrizing is followed by deposition of the core metal film 92.

The upper protective film 93b may be formed by oxidizing or nitrizing the upper surface portion of the core metal film 92 through  $O_2$  plasma treatment,  $N_2$  plasma treatment, or annealing in an oxidizing atmosphere.

Alternatively, the upper protective film 93b may be formed through reactive sputtering with a sputtering gas including  $O_2$ ,  $N_2$ , or  $N_2O$  gas at the final deposition stage of the core metal film 92.

5           As shown in Fig. 1E, the metal film stack is then patterned through a photolithography technique using a resist pattern 10 as a mask to form source and drain electrodes 7, 8 and data lines (not shown) so that the source and drain  
10 electrodes 7, 8 overlap the heavily doped amorphous silicon film 62. The source electrode 7 includes a lower refractory metal layer 71, a lower protective layer 73a, a core metal layer 72, a upper protective layer 73b, and an upper  
15 refractory metal layer 74, which are respectively formed from the refractory metal film 91, the lower protective film 93a, the core metal film 92, the upper protective film 93b, and the upper refractory metal film 94. Correspondingly, the  
20 drain electrode 8 includes a lower refractory metal layer 81, a lower protective layer 83a, a core metal layer 82, a upper protective layer 83b, and an upper refractory metal layer 84. The patterning of the metal film stack exposes a  
25 portion of the heavily doped amorphous silicon film 62 of the semiconductor film stack 6.

After patterning the metal film stack, the

side surfaces of the core metal layer 72, and 82 are then oxidized or nitrized through O<sub>2</sub> plasma treatment, N<sub>2</sub> plasma treatment, or annealing in an oxidizing atmosphere to form side protective layers 73c, and 83c. The lower, upper, and side protective layers 73a, 73b, and 73c may be collectively referred to as a protective layer 73. Correspondingly, the lower, upper, and side protective layers 83a, 83b, and 83c may be collectively referred to as a protective layer 83.

After the resist pattern 10 is stripped off, as shown in Fig. 1F, the exposed portion of the heavily doped amorphous silicon film 62 is dry-etched using the source and drain electrodes 7, 8 as a mask. It should be noted that the surface portion of the amorphous silicon film 61 may be etched by the dry-etching. This dry-etching forms a channel region 9 to complete an inversely staggered TFT. An etchant used for this dry-etching includes fluorine based chemicals, such as fluorocarbon. The etchant may additionally include chlorine based chemicals.

Alternatively, the exposed portion of the heavily doped amorphous layer 62 may etched using the resist mask 10 as a mask. In this case, the resist mask 10 is stripped off after the etching.

The protective layers 73, and 83

effectively avoids the corrosion of the core metal films 72 and 82 during and after the dry-etching using fluorine and/or chlorine based chemicals. The use of fluorine and/or chlorine based chemicals potentially causes corrosion of the sides of the core metal films 72 and 82 during dry-etching. Furthermore, subjecting the device structure to the atmosphere may cause undesirable production of hydrofluoric and/or hydrochloric acids through reaction of residual fluorine and/or chlorine based chemicals and moisture of the atmosphere, and the produced acids potentially corrodes the core metal films 72 and 82. However, the protective layers 73, and 83, which is resistive against chemicals, effectively prevent the core metal films 72, and 83 from being corroded.

In addition, the protective layers 73, and 83, which are disposed between the core metal films and the refractory metal films, effectively prevent the undesirable reaction therebetween, and thereby improve the heat resistance of the interconnections. Improvement of the heat resistance is of much importance for implementing the remaining fabrication processes, typically including heat treatment for stabilizing transistor characteristics, passivation using a

plasma chemical vapor deposition, and so forth.

In another alternative embodiment, as shown in Fig. 2A, the metal film stack of the refractory metal film 91, the lower protective film 93a, the core metal film 92, the upper protective film 93b, and the upper refractory metal film 94 are deposited before patterning the semiconductor film stack 6. As described below, the metal film stack and the semiconductor film stack 6 are then patterned using a single photolithography process. The fabrication process in this embodiment preferably reduces the number of necessary photolithography steps.

In this embodiment, as shown in Fig. 2B, after depositing the metal film stack, the resist pattern 10 is formed thereon through a photolithography technique using a gray tone mask so that the resist pattern 10 has a thinner portion 110.

The metal stack is then patterned with the resist pattern 10 used as a mask to expose a portion of the semiconductor film stack 6. After patterning the metal stack, the side surfaces of the core metal film 92 are then oxidized or nitrized through  $O_2$  plasma treatment,  $N_2$  plasma treatment, or annealing in an oxidizing atmosphere to form side protective films 93c.

After forming the side protective layers 93c, as shown in Fig. 2C, the semiconductor film stack 6 is then etched with an etchant gas including fluorine based chemicals, such as fluorocarbon, using the resist pattern 10 used as a mask. The etchant may additionally include chlorine based chemicals. As is the case of the protective layers 73 and 83 described before, the protective films 93a, 93b, and 93c effectively avoids corrosion of the core metal film 92 resulting from the fluorine and/or chlorine based chemicals.

After etching the semiconductor film stack 6, as shown in Fig. 2D, the resist pattern 10 is subjected to ashing to remove the top portion of the resist pattern 10. This ashing exposes a portion of the upper refractory metal film 94 to form a pair of separated resist patterns 210.

As shown in Fig. 2E, the metal film stack is then patterned to form the source and drain electrodes 7, and 8. This patterning exposes a portion of the heavily doped amorphous silicon film 62 of the semiconductor film stack 6. After patterning the metal film stack, the side surfaces of the core metal layers 72 and 82 are then oxidized or nitrized through  $O_2$  plasma treatment,  $N_2$  plasma treatment, or annealing in an



oxidizing atmosphere to form the protective layers 73c and 83c.

The resist patterns 210 is then stripped off as shown in Fig. 2F.

5           As shown in Fig. 2G, the exposed portion of the heavily doped amorphous silicon film 62 is dry-etched using the source and drain electrodes 7, 8 as a mask. The etchant may additionally include chlorine based chemicals. This dry-  
10 etching forms a channel region 9 to complete an inversely staggered TFT. It should be noted that the surface portion of the amorphous silicon film 61 may be etched by this etching. An etchant used for this dry-etching includes fluorine based  
15 chemicals, such as fluorocarbon. As mentioned above, the protective layers 73 and 83 are effective for avoiding corrosion potentially caused by fluorine and/or chlorine based chemicals.

20           In conclusion, the aforementioned method for fabricating interconnections effectively improves corrosion resistance through forming the protective layers 73 and 83 around the core metal layers 72 and 82. The protective layers 73 and 83,  
25 which are disposed between the core metal layers 72, and 82 and the refractory metal layers 71, 81, 74, and 84, are also effective for improving heat

resistance of the interconnections.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present  
5 disclosure of the preferred form has been changed in the details of construction and the combination and arrangement of parts may be resorted to without departing from the scope of the invention as hereinafter claimed.